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LUMINARY MEMO # 147

TO: Distribution

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DATE: May 5, 1970

SUBJECT: Terrain Model Routine for Luminary

GENERAL

Starting with the 1D release for Apollo 14, Luminary provides a model of the terrian profile anticipated in the vicinity of the landing site. The terrain is modeled by a series of line segments leading to the nominal landing site. Each line segment is defined by a pair of single-precision erasables; one defines the slope of the segment, the other defines the range from the nominal site to the segment end farther from the site. The modeled terrain altitude is continuous at the intersections of the segments.

The terrain model routine was designed to minimize the computation time, the padload and unshared erasables required, and the fixed memory words required, in that order. Although absolutely no penalties were paid in computation time or words to maintain certain design specifications such as the slope resolution and the range capacity, we believe all of the design specifications of the terrain model routine are adequate.

SPECIFICATIONS

1. 5 segments maximum. The number of segments can be increased indefinitely by reserving additional erasable padloads, two per segment, and changing one word in fixed memory. There is no increase in words of fixed memory used. The number of segments can be reduced by loading zero's for the slopes of un-needed segments.

2. The routine models the terrain at ranges farther from the landing site than the farthest segment by extending indefinitely the far end of the farthest segment at constant altitude.

3. The maximum range from the landing site to the far end of the farthest segment is $2^{18}-2^{4}$ meters, (262,128 meters = 860,000 ft. = 141.5 nautical miles = approximately half the braking phase).

4. Range resolution = 16 meters.

5. Altitude resolution due to range resolution = range resolution x slope. (for 0.1 radian = 5.73^{o}, altitude resolution = 1.6 meter = 5.25 ft. Thus the altitude displays will jump less than one foot per degree slope each time there is a one bit change in the range.)

6. Slope resolution = $1/2^{8}$ radians = 3.9 milliradians = $.224^{o}$. This means that an approach phase of 25,000 ft. can be modeled to a resolution of just under 100 ft. The resolution over the maximum range of the terrain model is 2^{10} meters = 1024 meters = 3360 ft. This resolution could be reduced at a cost of one word per factor of two reduction in resolution, and negligible increase in computation time.

7. Maximum slope = arctan (2^{6}) = 89.1^{o}. Any reduction in slope resolution (item 6 above) would reduce the argument of the arctan by the same factor.

8. Running time = 6.59 + 1.02 N milliseconds, where N is the number of segments used in the calculations at the current range of the LM. Thus, with 5 segments, the time is 11.69 milliseconds, and the time reduces as the LM approaches the landing site and segments are dropped. Ten (10) milliseconds is 1/2 % of the computer duty cycle.

9. The terrain model is omitted in P66, and it can be locked out at any time by entering verb 68. Caution: Once the terrain model is locked out, it cannot be retrieved except by the tedious process of resetting the flag: V 25 N 7 E 75 E 2000 E E.

   Eliminating the terrain model produces a discontinuity in ΔH (except when the terrain model altitude is coincidentally zero). The discontinuity in ΔH will produce a gradual change in the navigated altitude which could produce a pitch change in P63 or P64. Since P66 guidance does not use position data, only velocity, eliminating the terrain model cannot affect P66 attitude, but will have a gradual effect on the displayed altitude.

ERASABLE PADLOADS AND TERRAIN MODEL ROUTINE FLOW

The padloads define a model of the terrain altitude above a circular moon versus the Z component in platform coordinates of the vector from the lading site to the point of intersection of the landing radar altitude beam with the lunar surface. The scaling of range allows the routine to model 8.64^{o} central angle of the lunar surface. Therefore, the curvature of the moon is important. Figure 1 shows the mapping parameters to use for the terrain model padloads, accounting for curvature. Figure 2 shows an out-of-scale model of Fra Mauro profile II and the corresponding padloads. Note that because the independent variable is range as defined above, it is negative prior to reaching the landing site. (An additional reason for defining range negative prior to the site was a reduction of one work in the routine). The padloads are scaled as follows:

ABSCISSAE	2^{18} meters
SLOPES	2^{06} radians

Figure 3 shows the flow of the terrain model routine. Nomenclature definitions are:

ΔH — The altitude increment used to update the position vector by the equations

$$\Delta \underline{r}_P = \Delta H \, W(1 - HCALC/HMAX) \, UNIT(\underline{r}_P)$$

$$\underline{r}_P = \underline{r}_P + \Delta \underline{r}_P$$

ΔH^* — A temporary register for accumulating ΔH due to radar and terrain. The altitude increment must not be stored in the permanent register ΔH until it is complete. Otherwise Noun 68 and telemetry could fetch a partial ΔH and give an erroneous indication that the state vector fails to converge.

$H(LR)$ — Altitude computed from landing radar by the equation

$$H(LR) = - \underline{r}_{LRP} \cdot UNIT(\underline{r}_P)$$

HCALC — Altitude calculated from the state vector post-incorporation of inertial data and pre-incorporation of radar and terrain data.

HMAX — Maximum altitude for altitude updates (erasable padload)

Range — Z component in platform coordinates, of the vector from the landing site to the point of intersection is the LR altitude beam with the lunar surface.

$\underline{r}_P$ — Position vector, platform coordinates

$\Delta\underline{r}_P$ — Update to $\underline{r}_P$ from radar and terrain

$\underline{r}_{LRP}$ — Landing radar altitude beam vector, platform coordinates. Beam vector to the lunar surface from the landing radar antenna.

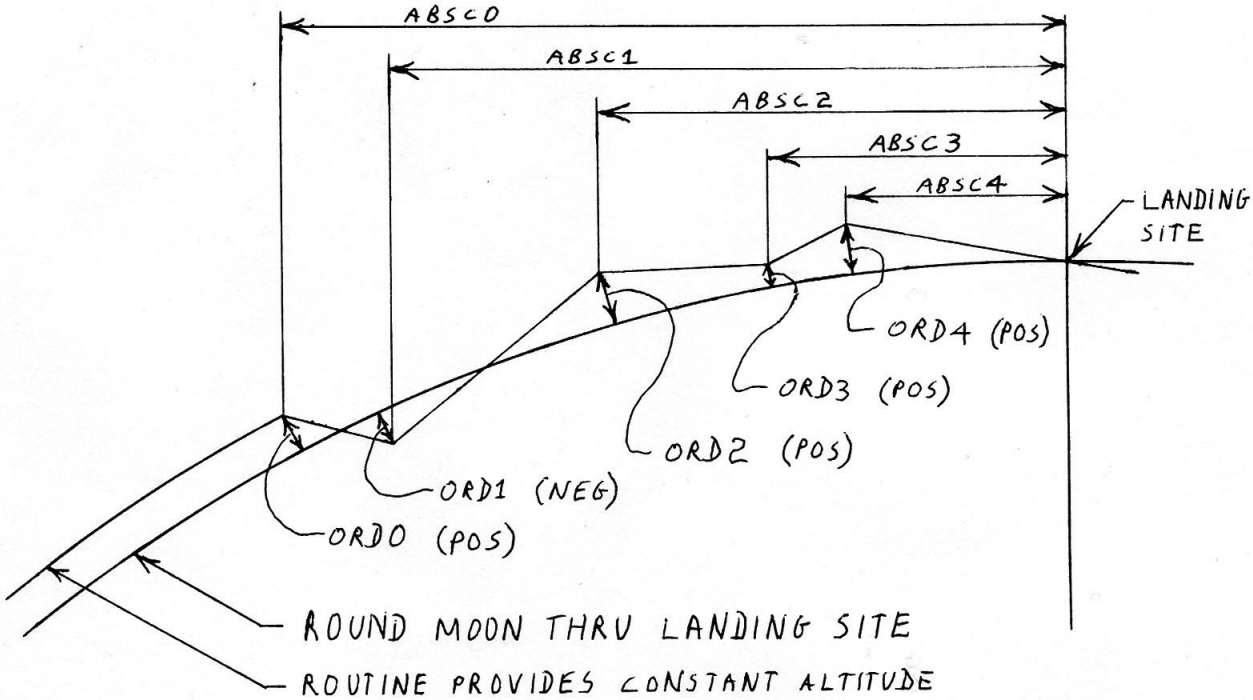
$\underline{r}_{SP}$ — Landing site vector, platform coordinates

W — The zero altitude value of the altitude weighting function (erasable padload)

NOTERFLAG — No terrain flag. This flag is reset by the ignition algorithm and set by P66 and V68.

ABSC's — Terrain model abscissae (erasable padloads)

SLOPE's — Terrain model slopes (erasable padloads)



ALL ABSCISSAE ARE NEGATIVE

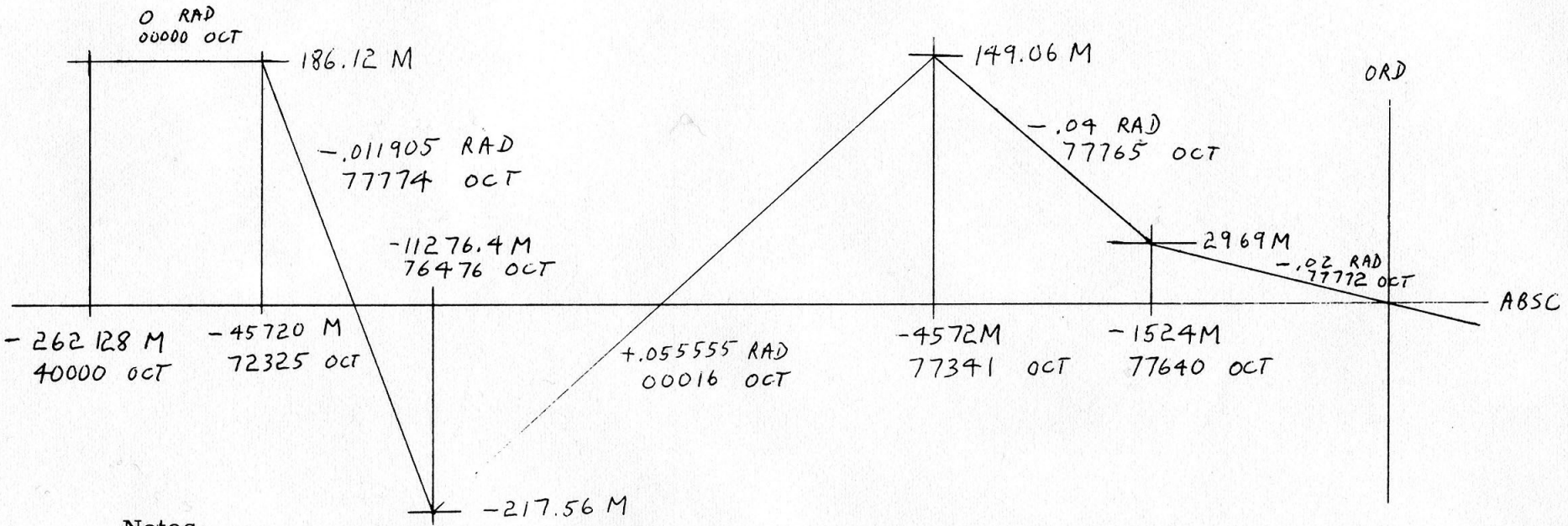
TYPICAL SLOPE PADLOADS ARE COMPUTED AS

$$SLOPE2 = (ORD3 - ORD2)/(ABSC3 - ABSC2)$$

$$SLOPE4 = ORD4 / ABSC4$$

DETERMINING PADLOADS FROM MAP PARAMETERS

FIGURE 1



Notes:

1. The metric abscissae and slopes are those used to determine the octals and do not correspond exactly to the octals.

2. The ordinates are computed from the octal abscissae and octal slopes and do not correspond exactly to the metric abscissae and slopes. The ordinates do represent exactly the terrain model defined by the padloads.

3. SLOPE0 = 0 reduces the number of segments modeled from five to four.

FRA MAURO TERRAIN PROFILE II

(NOT TO SCALE)

FIGURE 2

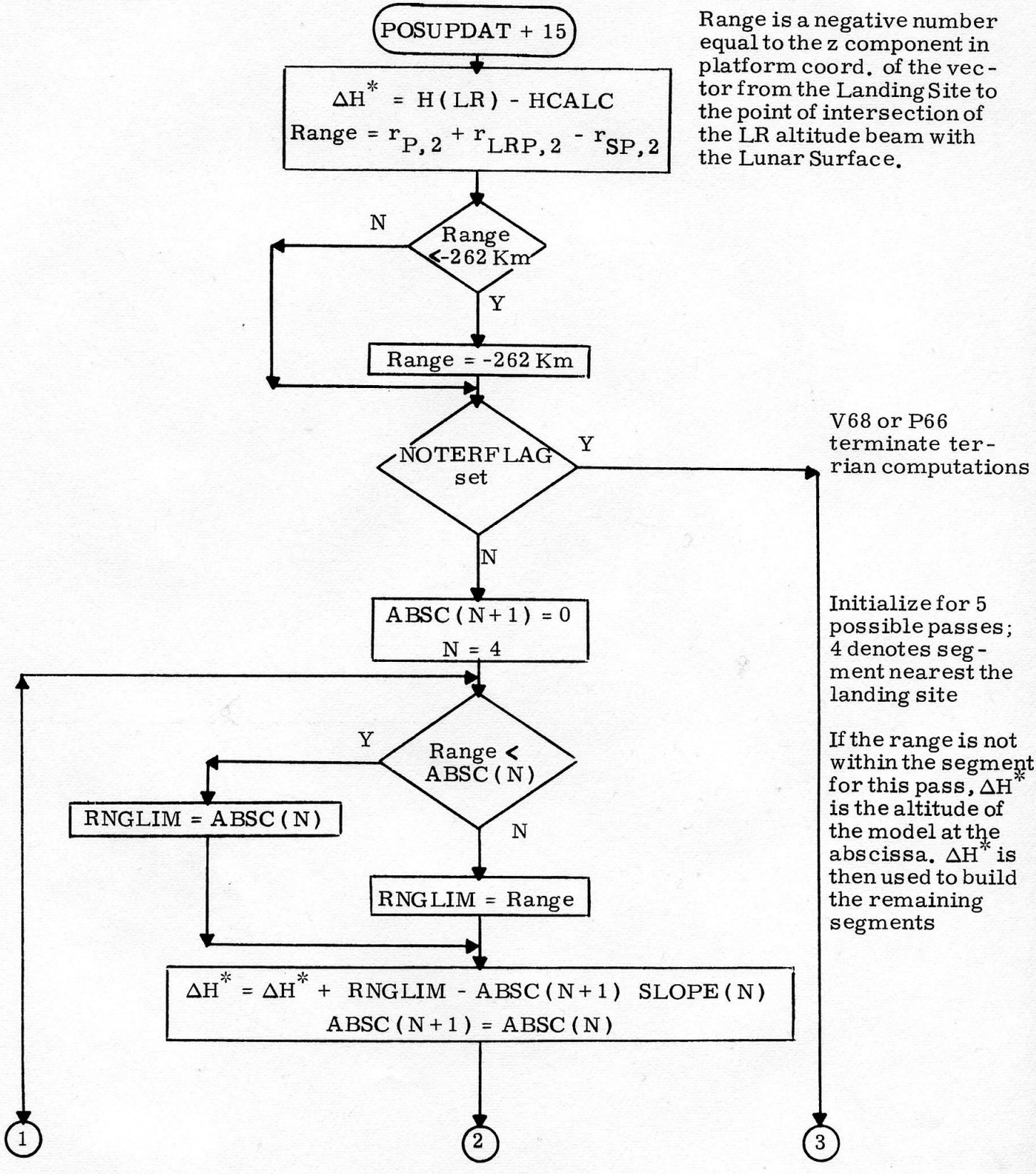


Figure 3

Terrain Model Routine Flow

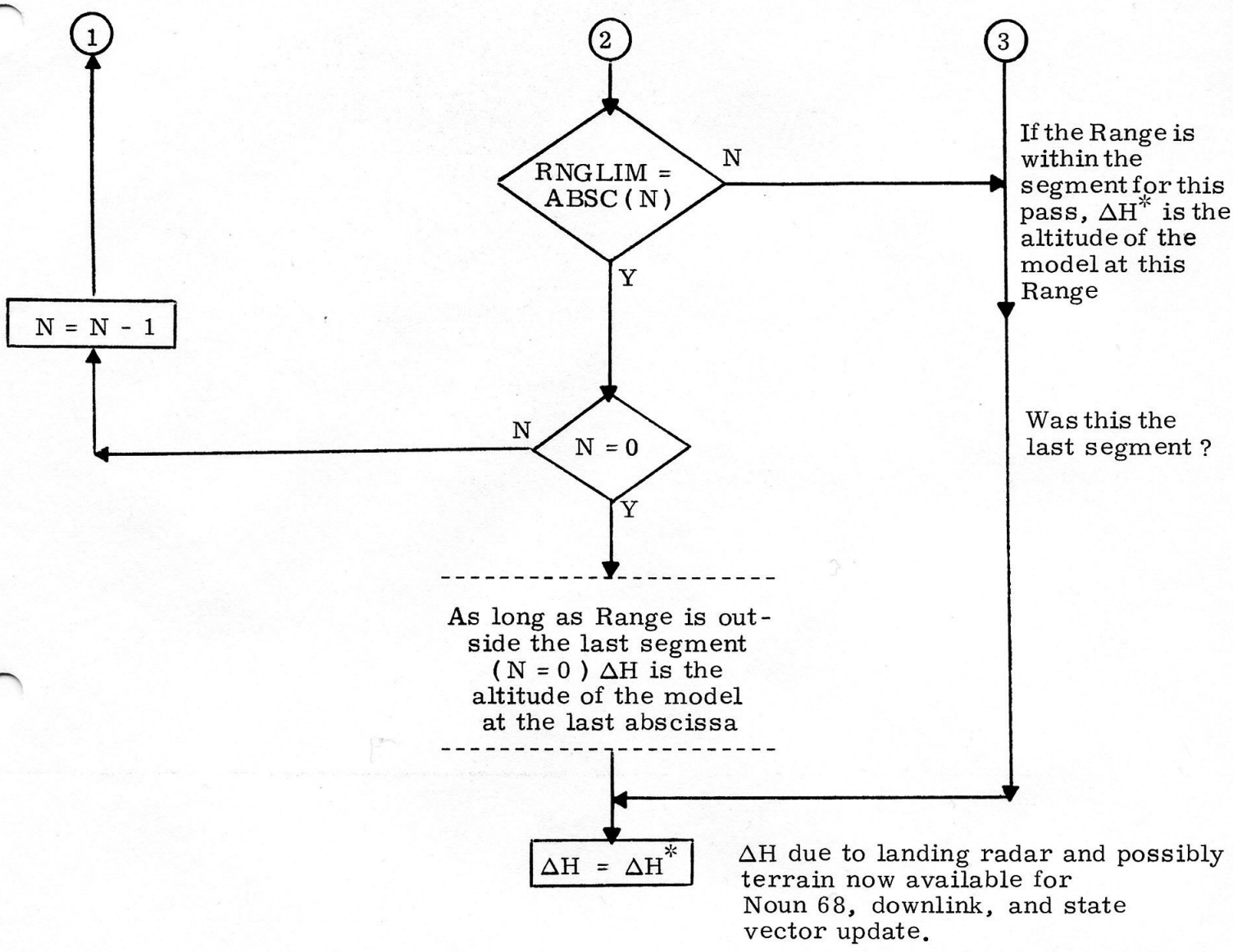


Figure 3 (cont.)
Terrain Model Routine Flow